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(56) Documents Cited by ISA  
None

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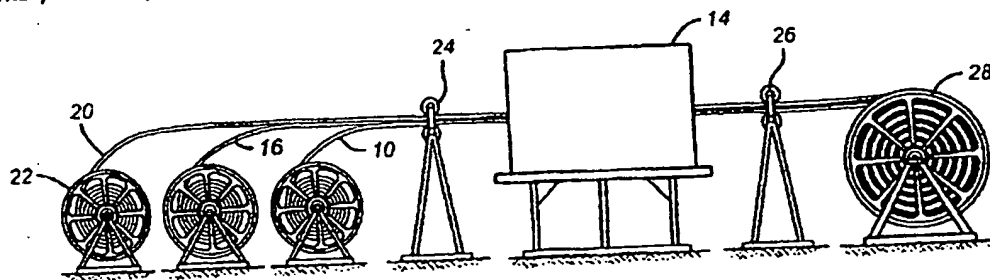
(72) Inventor(s)

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(54) Abstract Title

**Multi-layer screen and downhole completion method**

(57) A downhole completion method and an expandable filtration apparatus are disclosed. The filter assembly comprises a plurality of layers beginning with a coated perforated base pipe. The coating reduces the force required for expansion. A drainage layer overlays the base pipe with the filtration layer above it. The drainage layer improves flow through the filtration layer and protects it from burrs in the base pipe. A filtration enhancement layer fits over the filtration layer and an outer shroud protects the assembly during run in. The assembly can be used as made or expanded downhole in one or a series of expansions.



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**WO 02/023009 A3**

(51) International Patent Classification<sup>7</sup>:  
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E21B 43/08,

(74) Agents: CARSON, Matt et al.; Baker Hughes Incorporated, Suite 1200, 3900 Essex Lane, Houston, TX 77027 (US).

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(84) Designated States (*regional*): ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

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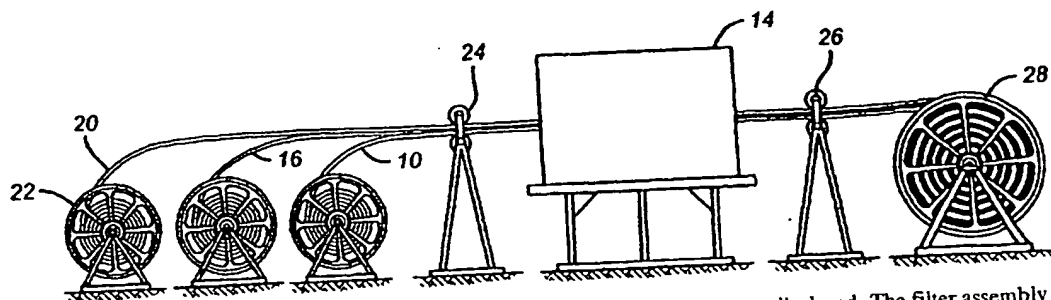
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For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: MULTI LAYER SCREEN FOR DOWNHOLE USE.



(57) Abstract: A downhole completion method and an expandable filtration apparatus are disclosed. The filter assembly comprises a plurality of layers beginning with a coated perforated base pipe (10). The coating (18) reduces the force required for expansion. A drainage layer (24) overlays the base pipe with the filtration layer (26) above it. The drainage layer improves flow through the filtration layer and protects it from burrs in the base pipe. A filtration enhancement layer fits (32) over the filtration layer and an outer shroud (34) protects the assembly during run in. The assembly can be used as made or expanded downhole in one or a series of expansions.

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## INTERNATIONAL SEARCH REPORT

International Application No

PCT/US 01/27581

A. CLASSIFICATION OF SUBJECT MATTER  
IPC 7 E21B43/08 E21B43/10 B01D29/00

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)  
IPC 7 E21B B01D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	GB 2 336 383 A (BAKER HUGUES INCORPORATED) 20 October 1999 (1999-10-20) claim 1 page 5, line 18 - line 20	1
A	US 4 483 399 A (COLGATE) 20 November 1984 (1984-11-20) column 6, line 59 - line 63 column 7, line 8 - line 11 claim 3	1
A	US 3 680 183 A (SUNDBERG) 1 August 1972 (1972-08-01) column 14, line 15 - line 27 column 7, line 42 - line 46 column 2, line 12 - line 21	1
-/-		



Further documents are listed in the continuation of box C.



Patent family members are listed in annex.

## \* Special categories of cited documents:

- \*A\* document defining the general state of the art which is not considered to be of particular relevance
- \*E\* earlier document but published on or after the international filing date
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- \*O\* document referring to an oral disclosure, use, exhibition or other means
- \*P\* document published prior to the international filing date but later than the priority date claimed

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- \*X\* document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
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\*G\* document member of the same patent family

Date of the actual completion of the international search

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# INTERNATIONAL SEARCH REPORT

International Application No  
PCT/US 01/27581

## C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5 979 551 A (UBAN) 9 November 1999 (1999-11-09) column 1, line 54 - line 66	1
A	WO 00 50733 A (SHELL OIL COMPANY) 31 August 2000 (2000-08-31) page 6, line 10 - line 15 page 1, line 24 - line 28	15,16
Y		17,18
Y	WO 00 37766 A (ASTEC DEVELOPMENTS LIMITED) 29 June 2000 (2000-06-29) abstract	17,20,21
A	GB 2 344 606 A (SHELL INTERNATIONALE RESEARCH MAATSCHAPPIJ B.V.) 14 June 2000 (2000-06-14) page 7, line 24 - line 30	15
A	EP 0 952 306 A (SHELL INTERNATIONALE RESEARCH MAATSCHAPPIJ B.V.) 27 October 1999 (1999-10-27) column 6, line 54 -column 7, line 1; claim 10	15
A	WO 98 00626 A (SHELL INTERNATIONALE RESEARCH MAATSCHAPPIJ B.V. ) 8 January 1998 (1998-01-08) abstract	15
A	WO 95 25239 A (ATLAS COPCO GEOTECHNICAL DRILLING AB) 21 September 1995 (1995-09-21) page 2, line 21 - line 26	15
A,P	WO 01 33037 A (SHELL OIL COMPANY) 10 May 2001 (2001-05-10) page 27, line 22 - line 31	15
T	WO 01 98623 A (SHELL OIL COMPANY) 27 December 2001 (2001-12-27) claim 1	15
A	WO 00 50732 A (SHELL OIL COMPANY) 31 August 2000 (2000-08-31) page 4, line 15 - line 25	20
A	GB 2 329 916 A (BAKER HUGUES INCORPORATED) 7 April 1999 (1999-04-07) page 9, line 18 - line 25	20
A	US 3 099 318 A (MILLER) 30 July 1963 (1963-07-30) column 7, line 17 - line 32	20

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## INTERNATIONAL SEARCH REPORT

International Application No

PCT/US 01/27581

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT		
Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
T	US 6 354 373 B1 (VERCAEMER) 12 March 2002 (2002-03-12) abstract	20
X	US 5 901 789 A (DONNELLY) 11 May 1999 (1999-05-11) cited in the application column 5, line 1 - line 8 column 7, line 20 - line 34	24
Y	column 4, line 56 - line 59 column 5, line 33 - line 40	20,21
X	GB 2 326 896 A (SOFITECH N.V.) 6 January 1999 (1999-01-06) page 3, line 6 - line 9 page 9, line 14 - line 20; claim 3	24
Y		18
X	FR 2 771 133 A (DRILLFLEX SOCIETE ANONYME) 21 May 1999 (1999-05-21) page 6, line 30 - line 34 page 6, line 12 - line 22	24
A	US 5 611 399 A (RICHARD) 18 March 1997 (1997-03-18) cited in the application column 2, line 53 - line 66; figure 10	24
A	US 5 980 745 A (VOLL) 9 November 1999 (1999-11-09) column 3, line 3 - line 36; figure 3A	24
A	US 2 217 370 A (JOHNSTON) 8 October 1940 (1940-10-08) page 1, left-hand column, line 29 -right-hand column, line 2	24

# INTERNATIONAL SEARCH REPORT

International application No.  
PCT/US 01/27581

## Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This International Search Report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:  
because they relate to subject matter not required to be searched by this Authority, namely:
2. ☐ Claims Nos.:  
because they relate to parts of the International Application that do not comply with the prescribed requirements to such an extent that no meaningful International Search can be carried out, specifically:
3. ☐ Claims Nos.:  
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

## Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. ☒ As all required additional search fees were timely paid by the applicant, this International Search Report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this International Search Report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this International Search Report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest.
- ☒ No protest accompanied the payment of additional search fees.

FURTHER INFORMATION CONTINUED FROM PCT/SA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. Claims: 1-14

Expandable filter assembly for downhole use, comprising at least one annealed filtration layer.

2. Claims: 15-19

Expandable filter assembly for downhole use, comprising at least one filtration layer which is mounted on a coated pipe.

3. Claims: 20-23

Expandable filter assembly for downhole use, comprising at least one filtration layer and an expander capable of multi-stage expansion.

4. Claims: 24,25

Expandable filter assembly for downhole use, comprising at least one filtration layer including a weave having weft and warp wires.

# INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

PCT/US 01/27581

Patent document cited in search report		Publication date	Patent family member(s)	Publication date
GB 2336383	A	20-10-1999	AU 2373399 A NO 991765 A US 6263972 B1	21-10-1999 15-10-1999 24-07-2001
US 4483399	A	20-11-1984	NONE	
US 3680183	A	01-08-1972	NONE	
US 5979551	A	09-11-1999	NONE	
WO 0050733	A	31-08-2000	AU 3705800 A WO 0050733 A1 US 6253846 B1	14-09-2000 31-08-2000 03-07-2001
WO 0037766	A	29-06-2000	AU 1867900 A AU 1868700 A AU 1868800 A AU 1868900 A AU 1876600 A AU 1876800 A EP 1147287 A2 EP 1141517 A1 EP 1141515 A1 EP 1144802 A2 EP 1151180 A1 EP 1141518 A1 WO 0037766 A2 WO 0037771 A1 WO 0037768 A1 WO 0037767 A2 WO 0037772 A1 WO 0037773 A1 GB 2345308 A GB 2346632 A GB 2346400 A GB 2346909 A GB 2347445 A NO 20012596 A NO 20012597 A NO 20012598 A NO 20012599 A NO 20012600 A NO 20012865 A US 2002079106 A1 US 2002060079 A1	12-07-2000 12-07-2000 12-07-2000 12-07-2000 12-07-2000 12-07-2000 24-10-2001 10-10-2001 10-10-2001 17-10-2001 07-11-2001 10-10-2001 29-06-2000 29-06-2000 29-06-2000 29-06-2000 29-06-2000 29-06-2000 05-07-2000 16-08-2000 09-08-2000 23-08-2000 06-09-2000 27-07-2001 27-07-2001 30-07-2001 30-07-2001 30-07-2001 07-08-2001 27-06-2002 23-05-2002
GB 2344606	A	14-06-2000	AU 5933599 A BR 9906143 A DE 19958399 A1 NO 995991 A US 6263966 B1 US 2001047870 A1 US 2001047866 A1 US 2001045289 A1 US 2002060068 A1 US 2002050360 A1 US 2002060078 A1 US 2002040787 A1	08-06-2000 05-09-2000 13-07-2000 08-06-2000 24-07-2001 06-12-2001 06-12-2001 29-11-2001 23-05-2002 02-05-2002 23-05-2002 11-04-2002

## INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

PCT/US 01/27581

Patent document cited in search report		Publication date	Patent family member(s)	Publication date
GB 2344606	A		US 2002060069 A1	23-05-2002
EP 952306	A	27-10-1999	EP 0952306 A1	27-10-1999
			AU 742940 B2	17-01-2002
			AU 3823899 A	16-11-1999
			BR 9909832 A	26-12-2000
			CA 2328199 A1	04-11-1999
			CN 1298469 T	06-06-2001
			WO 9955999 A1	04-11-1999
			EP 1073825 A1	07-02-2001
			JP 2002513119 T	08-05-2002
			NO 20005307 A	20-10-2000
WO 9800626	A	08-01-1998	AU 723337 B2	24-08-2000
			AU 3442097 A	21-01-1998
			BR 9710016 A	10-08-1999
			CA 2260191 A1	08-01-1998
			WO 9800626 A1	08-01-1998
			EP 0907822 A1	14-04-1999
			JP 2001508144 T	19-06-2001
			NO 986171 A	22-02-1999
			NZ 333945 A	27-03-2000
WO 9525239	A	21-09-1995	SE 503459 C2	17-06-1996
			AT 185410 T	15-10-1999
			AU 680753 B2	07-08-1997
			AU 2089095 A	03-10-1995
			DE 69512651 D1	11-11-1999
			DE 69512651 T2	31-05-2000
			EP 0757768 A1	12-02-1997
			FI 963641 A	08-11-1996
			NO 963833 A	25-10-1996
			SE 9400867 A	16-09-1995
			WO 9525239 A1	21-09-1995
			US 5738388 A	14-04-1998
WO 0133037	A	10-05-2001	AU 1356601 A	14-05-2001
			WO 0133037 A1	10-05-2001
WO 0198623	A	27-12-2001	AU 6981001 A	02-01-2002
			WO 0198623 A1	27-12-2001
WO 0050732	A	31-08-2000	AU 3603800 A	14-09-2000
			BR 0008470 A	05-02-2002
			EP 1155218 A1	21-11-2001
			NO 20014038 A	20-08-2001
			WO 0050732 A1	31-08-2000
			US 6253850 B1	03-07-2001
GB 2329916	A	07-04-1999	US 6029748 A	29-02-2000
			AU 8707798 A	22-04-1999
			NO 984629 A	06-04-1999
US 3099318	A	30-07-1963	NONE	
US 6354373	B1	12-03-2002	NONE	
US 5901789	A	11-05-1999	AU 710745 B2	30-09-1999

**INTERNATIONAL SEARCH REPORT**  
Information on patent family members

International Application No  
**PCT/US 01/27581**

Patent document cited in search report		Publication date	Patent family member(s)	Publication date
US 5901789	A		AU 7568096 A	29-05-1997
			BR 9611456 A	17-02-1999
			DE 69617258 D1	03-01-2002
			DE 69617258 T2	25-07-2002
			DK 859902 T3	21-05-2002
			EA 980433 A1	29-10-1998
			WO 9717524 A2	15-05-1997
			EP 0859902 A2	26-08-1998
			JP 11514712 T	14-12-1999
			NO 982087 A	07-07-1998
			NZ 322015 A	28-10-1999
			US 6012522 A	11-01-2000
GB 2326896	A	06-01-1999	FR 2765619 A1	08-01-1999
			US 6250385 B1	26-06-2001
FR 2771133	A	21-05-1999	FR 2771133 A1	21-05-1999
			AU 1159199 A	07-06-1999
			WO 9925951 A1	27-05-1999
US 5611399	A	18-03-1997	NONE	
US 5980745	A	09-11-1999	US 5849188 A	15-12-1998
			US 5624560 A	29-04-1997
			US 5642781 A	01-07-1997
			AU 721349 B2	29-06-2000
			AU 5371396 A	23-10-1996
			BR 9604795 A	07-07-1998
			CA 2216973 A1	10-10-1996
			GB 2314282 A ,B	24-12-1997
			GB 2337709 A ,B	01-12-1999
			NO 974620 A	07-10-1997
			WO 9631271 A1	10-10-1996
US 2217370	A	08-10-1940	NONE	

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization  
International Bureau



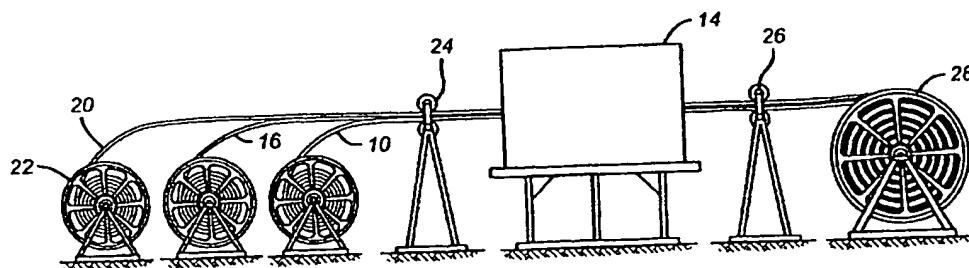
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**WO 02/23009 A2**

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- (74) Agents: **CARSON, Matt et al.**; Baker Hughes Incorporated, Suite 1200, 3900 Essex Lane, Houston, TX 77027 (US).
- (21) International Application Number: **PCT/US01/27581**
- (22) International Filing Date:  
6 September 2001 (06.09.2001)
- (25) Filing Language: English
- (26) Publication Language: English
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60/231,627 11 September 2000 (11.09.2000) US  
60/236,484 29 September 2000 (29.09.2000) US  
60/287,626 30 April 2001 (30.04.2001) US
- (71) Applicant: **BAKER HUGHES INCORPORATED**  
[US/US]; Suite 1200, 3900 Essex Lane, Houston, TX 77027 (US).
- (72) Inventors: **VOLL, Benn, A.**; 6706 Fawnciff Drive, Houston, TX 77069 (US). **PETERSON, Rick**; 206 Bell Maison, BSC, Lafayette, LA 70506 (US). **BROOME, John, T.**; 55 South Bristol Oak Circle, The Woodlands, TX 77382 (US). **DYSON, Ken**; 5010 Main Highway, St. Martinville, LA 70582 (US). **ANGELLE, Simon**; 1972 Bushville Highway, Arnaudville, LA 70512 (US). **BAUGH, John, L.**; 7519 Plum Tree Forest Court, Houston, TX 77095 (US).
- (81) Designated States (*national*): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CR, CU, CZ, DE, DK, DM, DZ, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, UZ, VN, YU, ZA, ZW.
- (84) Designated States (*regional*): ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).
- Published:**  
— without international search report and to be republished upon receipt of that report
- For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: **MULTI\_LAYER SCREEN AND DOWNHOLE COMPLETION METHOD**



(57) Abstract: A downhole completion method and an expandable filtration apparatus are disclosed. The filter assembly comprises a plurality of layers beginning with a coated perforated base pipe. The coating reduces the force required for expansion. A drainage layer overlays the base pipe with the filtration layer above it. The drainage layer improves flow through the filtration layer and protects it from burrs in the base pipe. A filtration enhancement layer fits over the filtration layer and an outer shroud protects the assembly during run in. The assembly can be used as made or expanded downhole in one or a series of expansions.

WO 02/23009 A2

Title: MULTI\_LAYER SCREEN AND DOWNHOLE  
COMPLETION METHOD

**Field of the Invention**

[0001] The field of this invention relates to downhole screens, which can be expanded into contact with the formation.

**Background of the Invention**

[0002] Downhole screens are used in a variety of different applications. As part of a common procedure called gravel packing, the screens are deposited adjacent the producing formation and the surrounding annular space is filled with sand known as gravel. Various fabrication techniques have been developed for manufacturing such screens and a typical example is illustrated in US Patent 5,611,399.

[0003] More recently it has been determined that it is desirable to reduce the size of the annular space between the screen and the formation. Reduction of the volume of the annular space around the screen discourages fluid flow along the screen, which, in turn, lessens the production of sand. In order to be able to produce the reservoir longer, it has been desirable to insert screens in well bores or laterals and thereafter expand them. A good example of the expansion techniques for a downhole screen is shown in U.S. Patent 6,012,522. In this patent, overlapping segments of screen are

placed on a base pipe, which is ultimately expanded from within when placed in position in the well bore or a lateral. The shortcoming of this technique is that portions of the filtering material must be moved relative to each other which subjects them to tearing which in turn can result in a failure of the expanded screen assembly to control the production of sand. Another shortcoming of such designs is the limited capacity to withstand collapse.

[0004] Other patents relating to pipe expansions are: U.S. Patent 5,901,789 and 5,366,012.

[0005] The main objective of the present invention is to allow easy installation of the screen to the desired location followed by expansion to reduce the volume of the annular space around the screen. Yet another object of the invention is to expand the screen against the formation to entirely eliminate the annular space around it. Yet another objective of the present invention is to allow the use of the structure of the screen downhole even without expansion. Another objective of the present invention is to decrease the amount of stress on the filtration member when expanded. Yet another objective of the present invention is to provide a significantly stronger structure for the finished product, which even after expansion presents a greater resistance to collapse. Another object of the invention is to provide, as much as possible, uniformity in the opening size of the filtration layer after the assembly is expanded. Another objective is to provide sufficient strength in the assembly, after expansion to allow it to better resist differential pressures. Still another objective is to reduce the effort required for expansion and to stage the overall expansion in discrete steps. These and other advantages of the present invention will be appreciated by

those skilled in the art from a review of the description of the preferred embodiment, which appears below.

### **SUMMARY OF THE INVENTION**

[0006] A downhole completion method and an expandable filtration apparatus are disclosed. The filter assembly comprises a plurality of layers beginning with a coated perforated base pipe. The coating reduces the force required for expansion. A drainage layer overlays the base pipe with the filtration layer above it. The drainage layer improves flow through the filtration layer and protects it from burrs in the base pipe. A filtration enhancement layer fits over the filtration layer and an outer shroud protects the assembly during run in. The assembly can be used as made or expanded downhole in one or a series of expansions.

### **BRIEF DESCRIPTION OF THE DRAWINGS**

[0007] Fig. 1 is cutaway view, partly in section, showing the filter assembly.

[0008] Fig. 2 is a section view along lines 2\_2 of Fig. 1.

[0009] Fig. 3 is a section view of a first step in a multi step expansion of the filter assembly.

[0010] Fig. 4 is a section view of a second step in a multi step expansion of the filter assembly.

[0011] Fig. 5 is a comparison performance chart comparing a known filter made by Baker Hughes called Excluder and two variations of the filter of the present invention.

### **DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT**

[0012] Referring to Fig. 1, the various layers of the preferred embodiment are shown. The innermost layer is a perforated base pipe 10, which has a plurality of openings 12. Base pipe 10 provides a firm foundation for the layers above. The pattern of the holes 12 is optimized to strike the best balance between collapse resistance after expansion and minimization of the force required to expand this layer and those positioned outside it, as will be described below. This optimization allows expansions in the range of up to about 30%. The base pipe 10 can have threads 14 and 16 at opposite ends to allow sections of the filter assembly A to be secured together, giving greater torsion and tension strength for the filter assembly A. A coating 18 made preferably from a plastic material can be applied to the inside of the base pipe 10. The Whitford Corp. manufactures the coating under the name Xylan 1052. Ultimately, when an expander 20 (see Fig. 3) is moved through base pipe 10, the coating 18 will reduce the required expansion force. The greater collapse resistance of the base pipe 10 promotes borehole stability after expansion. The optimization of the openings 12 promotes the highest expansion rate for a given material for base pipe 10 while still leaving sufficient inflow area through the pipe openings or perforations 12. Using round, rounded, or oval opening instead of slots provides for a mechanically stronger filter assembly A. In the preferred embodiment, the coating 18 is Xylan and it can provide a reduction in required force for a given expansion by as much as 50%. The coating 18 also helps resistance to galling by the expander 20 or a subsequent expander such as 22 (see Fig. 4).

[0013] Mounted above the base pipe 10 is a drainage layer 24. Drainage layer 24 is between base pipe 10 and filtration layer 26. The drainage layer 24 promotes flow

between the filtration layer 26 and the openings 12 of the base pipe 10. In the preferred embodiment, the drainage layer 24 is a weave, selected from a broad array of metals. A braided weave design is currently preferred, although other weave patterns can be used. The preferred material is available from Jersey Hose as 6" 304 SS Braid 600\_304B. The drainage layer 24 protects the filtration layer 26 from burrs or puckers around the edges of openings 12. In the event of high differential pressures due to production, the presence of the drainage layer 24 provides structural support for the filtration layer 26. The braided wire drainage layer 24 could be substituted with a shroud of some type, akin to outer shroud 34, that would have standoff from the base pipe 10.

[0014] Mounted over the drainage layer 24 is the filtration layer 26. The filtration layer 26 has uniform openings. The preferred material is a special type of Twill Dutch weave. This material gives very reliable uniformity to the opening size, after expansion. In this manner there can be confidence in the particle size, which will not pass filtration layer 26 while giving greater protection against plugging or the passage of too many particles. As shown in Fig. 1, the filtration layer 26 is oriented at an angle to the longitudinal axis of the filter assembly A. This angle can be in the range of about 10 to about 80 degrees with about 20 degrees being preferred. Orienting the filtering layer 26 at an angle allows minimization of change in opening size and uniformity, resulting from expansion. The Dutch Twill weave provides greater durability and particle holding capacity. Negative effects on hole size and uniformity as a result of expansion are further minimized by using a reverse weave Twill Dutch pattern. A reverse weave is one where the diameter of the weft (shute) wires 28 is

larger than the warp wires 30 by as much as about 50 percent. The combination of the angular placement of the filtration layer 26 by a spiral winding technique coupled with a reverse weave yields a more predictable and uniform opening size after expansion.

[0015] Mounted over the filtration layer 26 is the filtration enhancement layer 32. This layer promotes greater flow conductivity from the outermost layer, the outer shroud 34. Layer 32 acts as a coarse filter to layer 26 and prolongs the life of filtration layer 26. This can be seen in the graph of Fig. 5, where the addition of the filtration enhancement layer is curve 36. The same filter assembly A of the present invention but without the filtration enhancement layer 32 is illustrated by curve 38. Curve 40 represents the performance of a known product made by Baker Hughes called Excluder. Fig. 5 readily demonstrates that the addition of the filtration enhancement layer 32 nearly triples the time it takes to build up a backpressure of 40 PSIG for the same flow conditions. Leaving out the filtration enhancement layer 32 also makes that version of the present invention perform somewhat comparably to the known Excluder design. Several different weave types are suitable for layer 32 such as: square weave, Compound Balanced, Tight Tuck, and Braided Weave. A suitable Compound Balanced material is available from Porous Metal Products, model # CB\_3\_96\_192\_21/24. A metallic material is preferred.

[0016] The outer shroud 34 is preferably formed from spirally winding a perforated sheet into a tube. The hole size and pattern is optimized to facilitate expansion and yet provide sufficient collapse resistance in the expanded state. It is desired to have the inflow area of the openings maximized but to limit the opening size and use a

staggered pattern so that the outer shroud will not buckle or tear, when expanded. The primary purpose of the outer shroud 34 is to protect the layer below from damage during run in.

[0017] The layers can be joined together by swaging to reduce the outside diameter of the filter assembly A. Swaging also makes the various layers act as one with regard to expansion and provides greater strength against collapse after expansion. It is preferred to anneal the components individually before swaging or to anneal the filtration assembly A after all the components have been assembled. Doing this permits a greater degree of expansion without failure. This benefit is particularly applicable to the base pipe 10. The type of annealing envisioned is solution annealing to 1800 degrees F. Annealing of the base pipe 10 is done before applying the coating 18 due to the inability of the coating 18 to withstand the annealing temperatures. Sintering can be used instead of swaging to join the layers together. The layers are preferably assembled in the following manner: the braided wire of suitable drainage layer 24 is placed on the base pipe 10 which has previously been drilled with holes, coated and threaded. Then, the filtration layer 26 is wrapped at an angle over the top of the drainage layer 24. Another layer, called the filtration enhancement layer 32 is placed over the top of the filtration layer 26. Then, an outer shroud 34 is placed over the filtration enhancement layer 32 and the total package is run through a set of dies that swages or forces all components to vigorously contact each other.

[0018] The filter assembly A has the advantage of superior performance, whether it is expanded downhole or not. If it is not expanded, it can be gravel packed in the known manner. Figs. 3 and 4 illustrate a unique step-wise expansion technique. In a first

step, an expander 20 which may be a fixed cone or a cone with variable diameter is moved downwardly through the filter assembly A to achieve about a 15% expansion. At the lower end of the filter assembly A a cone latch 42 engages a fixed or variable diameter expander or cone 22 to increase the overall expansion to as much as 50%. As previously stated, more expansion steps can be used and different degrees of step\_wise expansion and overall expansion can be obtained with this technique. It should be noted that the second expansion does not necessarily have to proceed in a direction opposite the first expansion.

[0019] There are many applications of the filter assembly of the present invention. In horizontal open hole completions there are usually more than 1,000 feet of contact with the productive formation, sometimes in excess of 9,000'. Because there is so much contact the amount of production per foot is very low. In most cases if the theoretical production per foot was traveling into a screen directly opposite of the formation then the velocity would be too low to transport sand from unconsolidated formations or cause erosion. There are many wells in which erosion is taking place and sand is being produced. Presently there are a couple of theories that explain this occurrence. First the formations may be so unconsolidated that they simply fall apart when the pressure in the well bore used to control the well during drilling and completing the well is removed. This is referred to as hole or formation collapse. A second possibility is that fluid flows along the path of least resistance. This may be on the inside of a screen that is in place or along the outside. As the flow proceeds towards the beginning of the open hole section, the accumulative effects of production means the velocity is much higher towards the top section (beginning) of

the open hole. This velocity (accumulated flow) can be high enough on the outside of the screen to transport sand and to erode the formation and screen.

[0020] By expanding screen in an open hole horizontal well the annulus between the screen and the formation can be greatly reduced or even eliminated. Reduction of the annulus means greater resistance to flow and therefore production flow is reduced on the exterior of the screen and increased on the interior. The reduction in exterior flow means lower velocities near the well bore and therefore less sand transportability and less erosion effects.

[0021] Expansion can also aid in formation stability by physically supporting the formation if the screen is expanded until it is touching the formation. This support in turn could prevent the collapsing of the formation when the pressure in the well bore is reduced.

[0022] In cased hole applications filtration assembly A offers the advantage of a large inside diameter for remedial work below its installation. Another advantage is that in frac packs and gravel packs all that is necessary to do is to place the proppant or sand in the perforation tunnels and formation fractures. Annular packs between the screen and the casing, which are often difficult to achieve, are not necessary since expanding screen removes this annulus. The filter apparatus A could also be used in conjunction with a frac pack or gravel pack and subsequently expanded to back fill any voids in the annulus | pack or perforations not filled.

We claim:

1. An expandable filter assembly for downhole use, comprising:
  - a base pipe having an inside surface, a longitudinal axis, and a plurality of openings;
  - at least one filtration layer mounted over said base pipe, said layers each being annealed to facilitate subsequent expansion downhole.
2. The assembly of claim 1, wherein:
  - said filtration layer and said base pipe are individually annealed prior to being joined together.
3. The assembly of claim 1, wherein:
  - said filtration layer and said base pipe are annealed after being joined together.
4. The assembly of claim 1, wherein:
  - said filtration layer and said base layer are swaged together and said annealing further comprises solution annealing at up to about 1800 degrees F.
5. The assembly of claim 1, wherein:
  - said inside surface of said base pipe is coated to reduce the force needed for subsequent expansion.
6. The assembly of claim 5, further comprising:
  - an expander capable of multi-stage expansion of said base pipe and said filtration layer.
7. The assembly of claim 6, wherein:

said staged expansion occurs in a single direction.

8. The assembly of claim 6, wherein:

said staged expansion occurs in opposed directions.

9. The assembly of claim 6, wherein:

said base pipe is expanded in stages up to about 30% above its original dimension.

10. The assembly of claim 6, wherein:

said filtering layer comprises a weave having weft and warp wires and wherein one of said weft and warp wires is disposed at an angle of about 10-80 degrees with respect to the longitudinal axis of said base pipe.

11. The assembly of claim 10, wherein:

said weft wires have a larger diameter than said warp wires by as much as about 50%.

12. The assembly of claim 10, wherein:

said at least one filtration layer further comprises a woven drainage layer on said base pipe and a main filtration layer, said drainage layer protecting said main filtration layer from burrs in openings in said base pipe and providing mechanical support for said main filtration layer.

13. The assembly of claim 12, further comprising:

a filtration enhancement layer mounted over said main filtration layer and further comprising a weave, said drainage layer and said filtration

enhancement layer are spirally wound to orient wires therein in substantial alignment with said wires in said main filtration layer.

14. The assembly of claim 10, wherein:

said openings in said base pipe are round, rounded or oval.

15. An expandable filter assembly for downhole use, comprising:

a base pipe having an inside surface, a longitudinal axis, and a plurality of openings;

at least one filtration layer mounted over said base pipe,

said inside surface of said base pipe is coated to reduce the force needed for subsequent expansion.

16. The assembly of claim 15, wherein:

said coating is made of a plastic material and said openings are round, rounded or oval.

17. The assembly of claim 15, further comprising:

an expander capable of multi-stage expansion of said base pipe and said filtration layer.

18. The assembly of claim 17, wherein:

said filtering layer comprises a weave having weft and warp wires and wherein one of said weft and warp wires is disposed at an angle of about 10-80 degrees with respect to the longitudinal axis of said base pipe.

19. The assembly of claim 18, wherein:

said layers each being annealed to facilitate subsequent expansion downhole;  
said filtration layer and said base layer are swaged together and said annealing further comprises solution annealing at up to about 1800 degrees F.

20. An expandable filter assembly for downhole use, comprising:

a base pipe having an inside surface, a longitudinal axis, and a plurality of openings;  
at least one filtration layer mounted over said base pipe; and  
an expander capable of multi-stage expansion of said base pipe and said filtration layer.

21. The assembly of claim 20, wherein:

said base pipe is expanded in stages up to about 30% above its original dimension.

22. The assembly of claim 20, wherein:

said layers each being annealed to facilitate subsequent expansion downhole;  
said filtration layer and said base layer are swaged together and said annealing further comprises solution annealing at up to about 1800 degrees F.

23. The assembly of claim 22, wherein:

said filtering layer comprises a weave having weft and warp wires and wherein one of said weft and warp wires is disposed at an angle of about 10-80 degrees with respect to the longitudinal axis of said base pipe.

**24.** An expandable filter assembly for downhole use, comprising:

a base pipe having an inside surface, a longitudinal axis, and a plurality of openings;

at least one filtration layer mounted over said base pipe,

said filtering layer comprises a weave having weft and warp wires and wherein one of said weft and warp wires is disposed at an angle of about 10-80 degrees with respect to the longitudinal axis of said base pipe.

**25.** The assembly of claim 24, wherein:

said weft wires have a larger diameter than said warp wires by as much as about 50%.

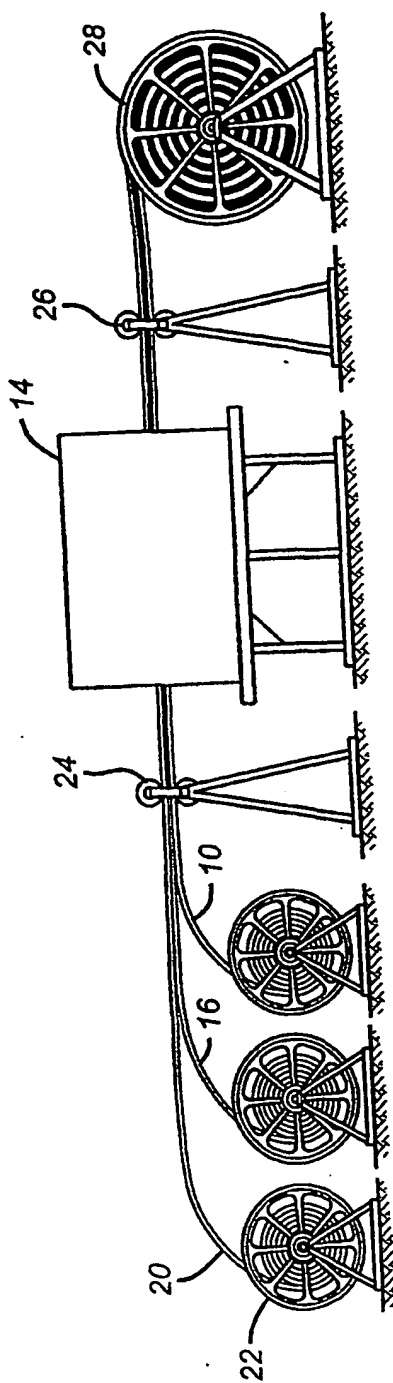


FIG. 1

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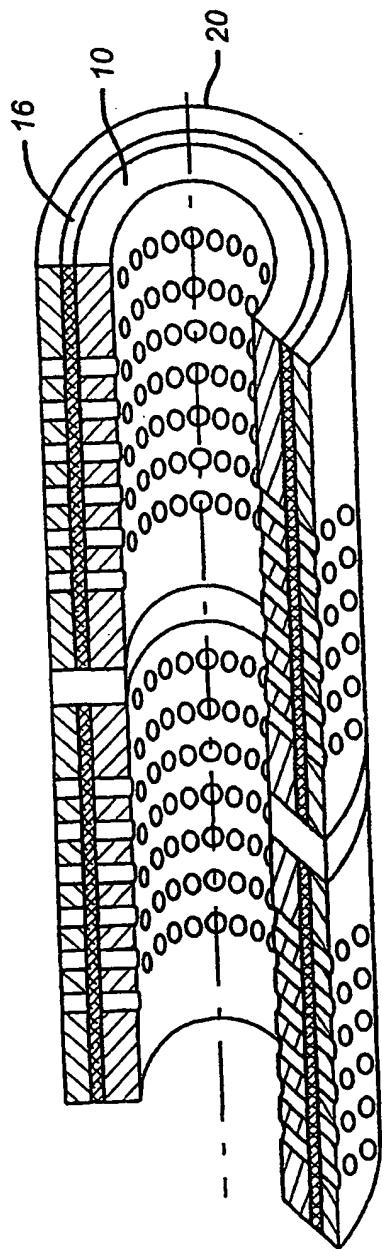


FIG. 2

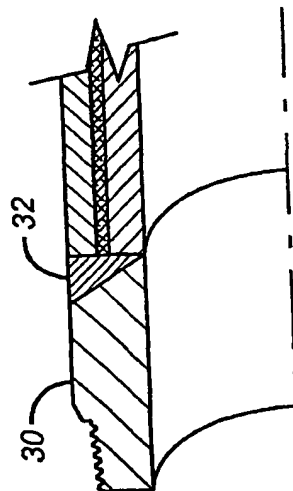


FIG. 4

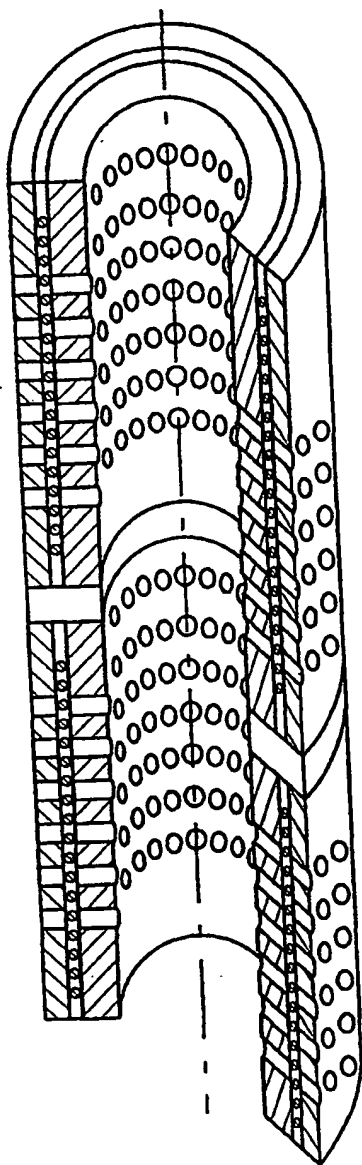


FIG. 3

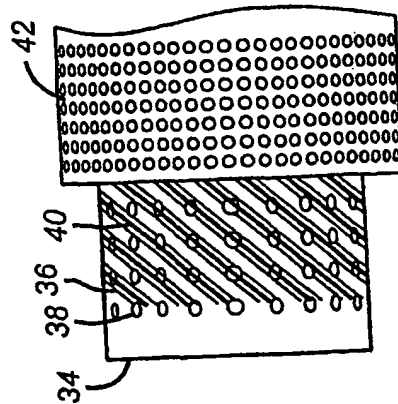


FIG. 5

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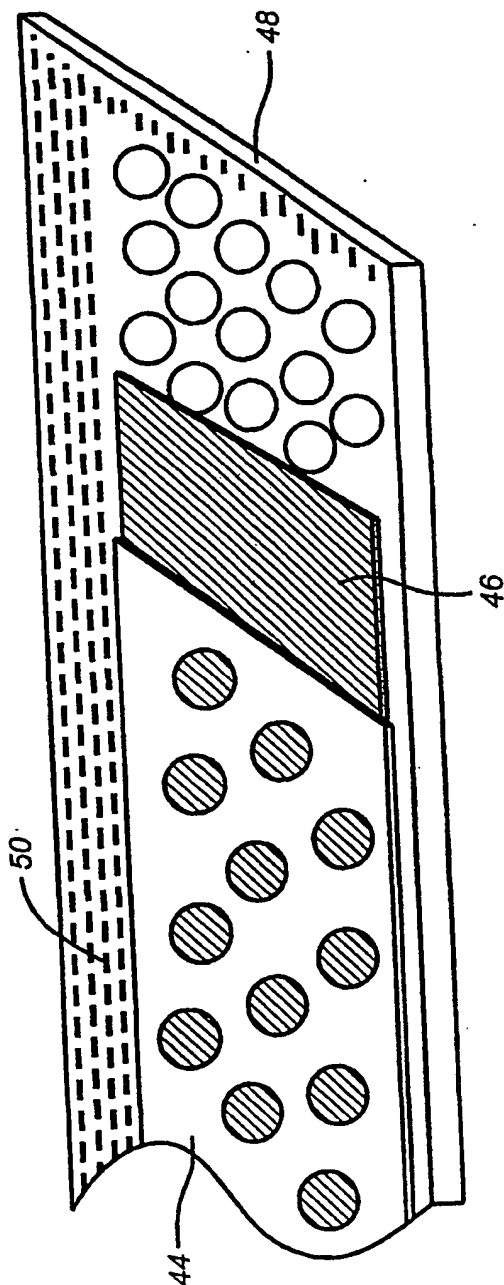


FIG. 6

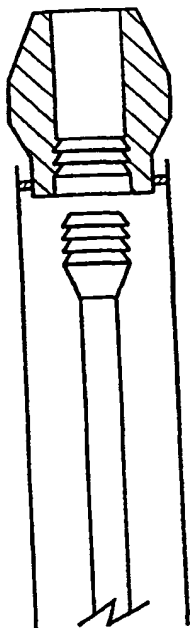


FIG. 9

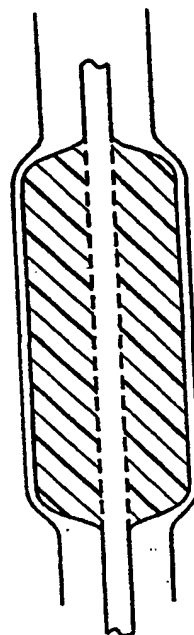


FIG. 11

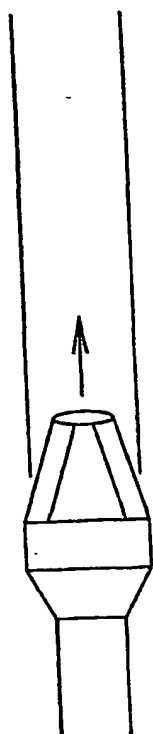


FIG. 7

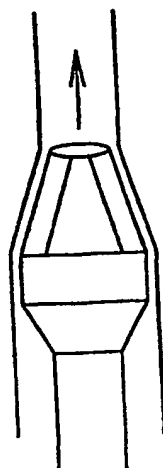


FIG. 8

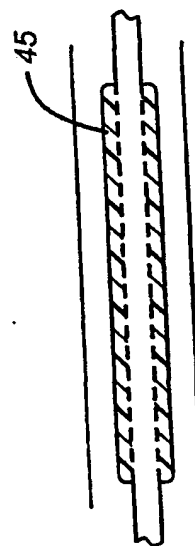


FIG. 10

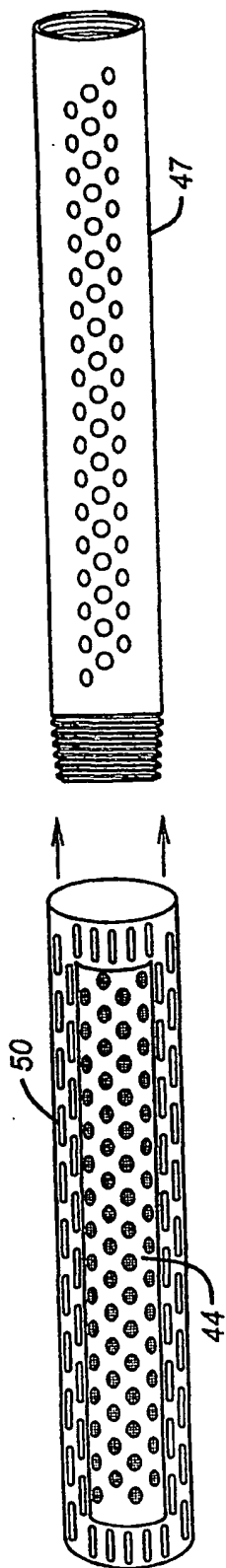


FIG. 12

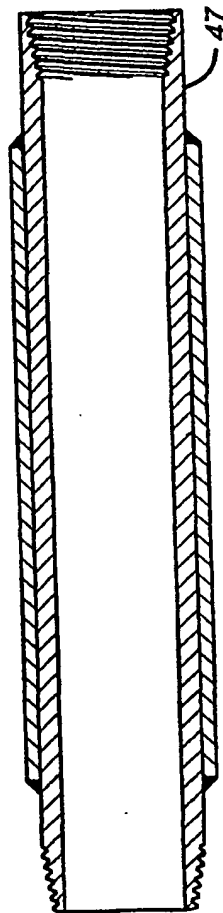


FIG. 13

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